PROJECT PATHFINDER

(NASA-TM-108768) PROJECT PATHFINDER: RESEARCH AND TECHNOLOGY TO ENABLE FUTURE SPACE MISSIONS (NASA) 31 p

N93-72545

Unclas

Z9/12 0160459

Research and Technology
To Enable
Future Space Missions

Exploration Technology

- *Planetary Rover*
- *Sample Acquisition, Analysis, and Preservation*
- *Surface Power*
- *Optical Communications*

Operations Technology

- *Autonomous Rendezvous and Docking*
- *Resource Processing Pilot Plant*
- *In-Space Assembly and Construction*
- *Cryogenic Fluid Depot*
- *Space Nuclear Power (SP-100)*

Humans-in-Space Technology

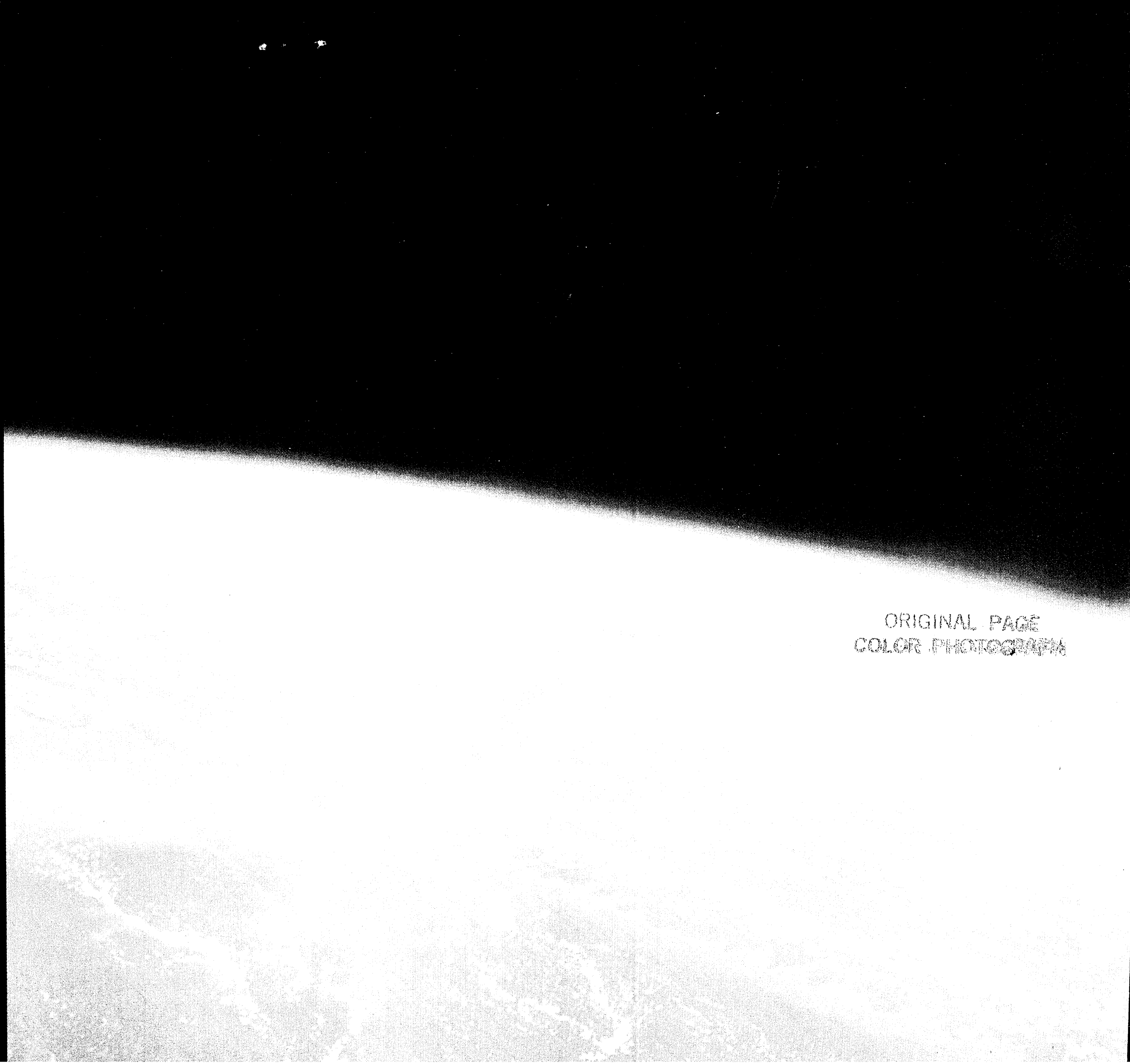
- *Extra-Vehicular Activity/Suit*
- *Human Performance*
- *Closed-Loop Life Support*

Transfer Vehicle Technology

- *Chemical Transfer Propulsion*
- *Cargo Vehicle Propulsion*
- *High-Energy Aerobraking*
- *Autonomous Lander*
- *Fault-Tolerant Systems*

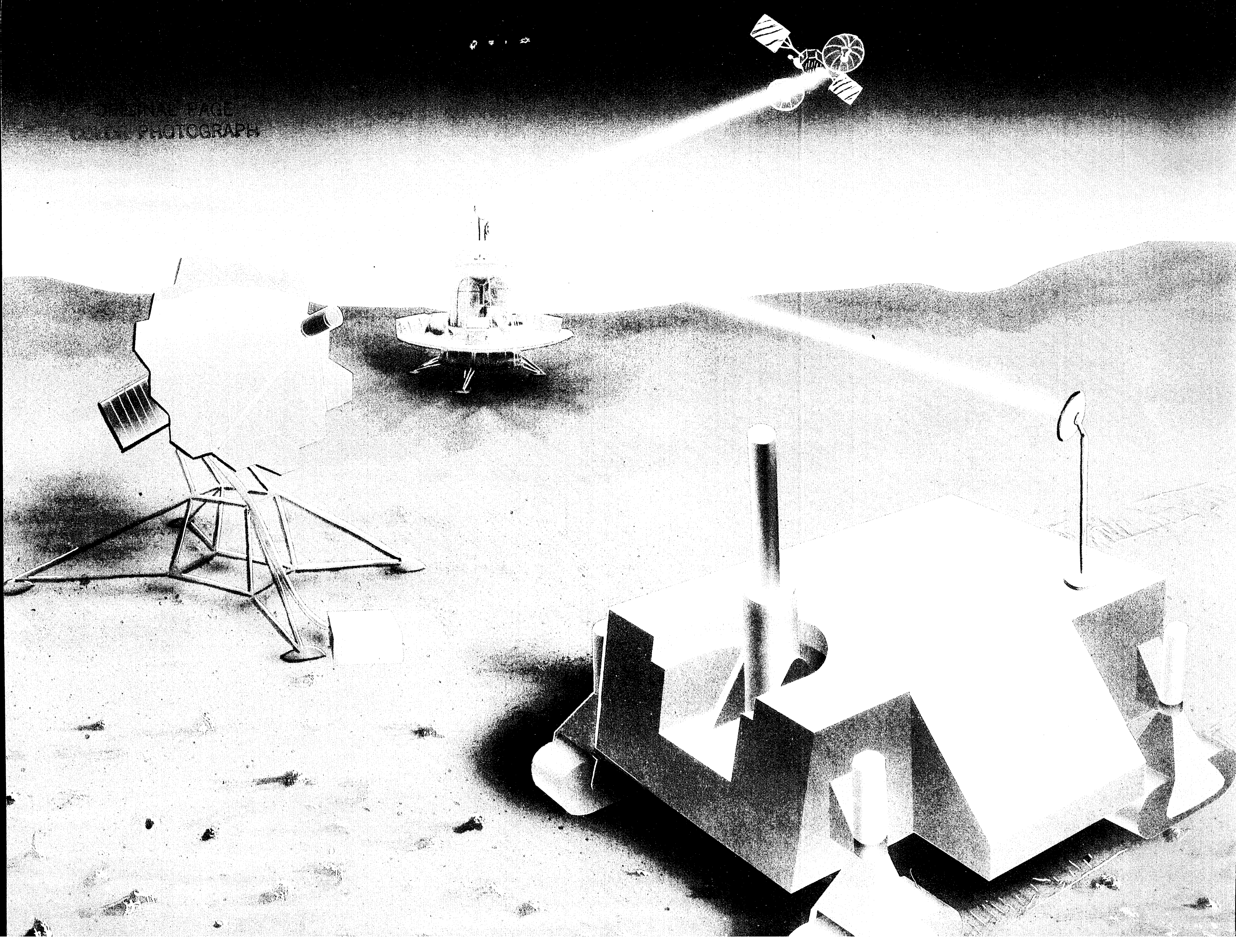
Mission Applications

- *Earth Orbit*
- *Lunar Operations*
- *Planetary Exploration*



Project Pathfinder is a research and technology program that will enable a broad set of space missions and strengthen the technology base of the United States civil space program. Building on the foundation established by the Civil Space Technology Initiative, Project Pathfinder will develop the emerging, innovative technologies that will make possible both new and enhanced missions, including an intensive study of the Earth, a return to the Moon, piloted missions to Mars, and the continuing robotic exploration of the Solar System. Through a strong partnership between NASA and U.S. industry and universities, Project Pathfinder will—as the Apollo program did in the 1960s—push American technology forward, while making future successes in space possible.

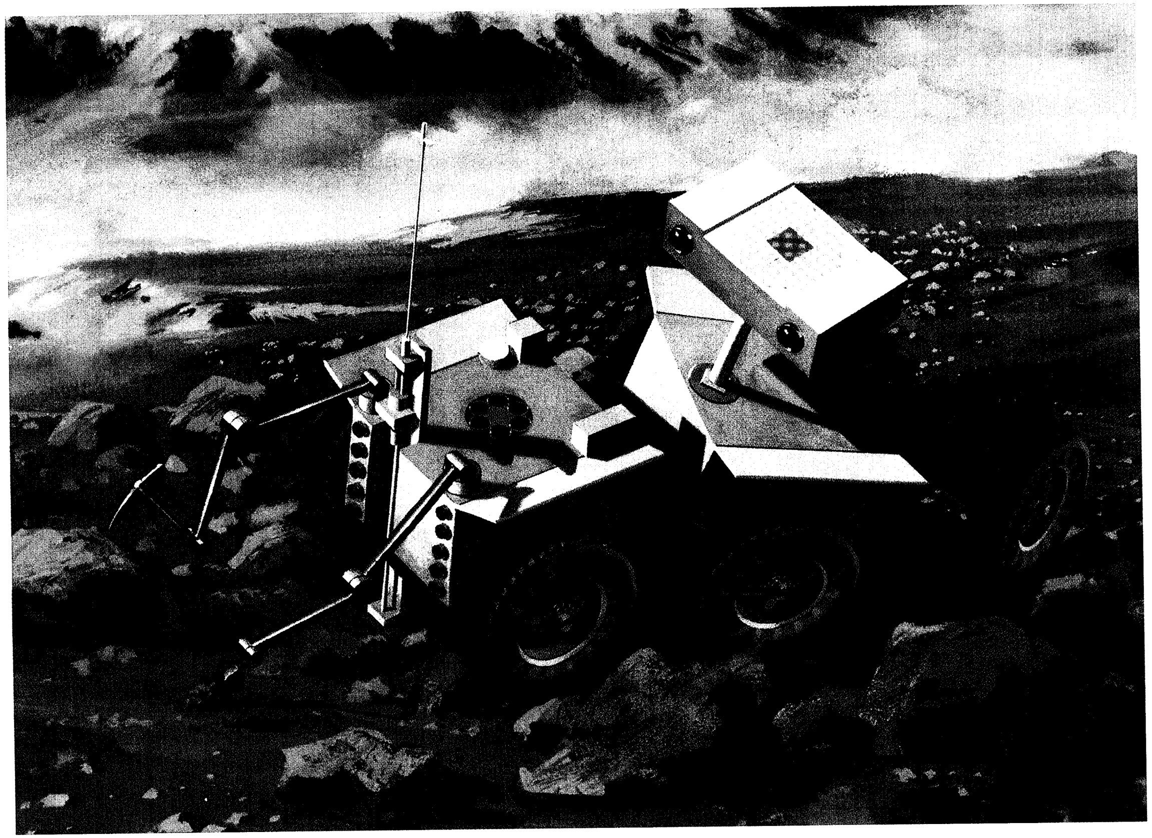
Project Pathfinder is organized around four major thrusts:(1) Exploration, (2) Operations, (3) Humans-in-Space, and (4) Transfer Vehicles. Each thrust focuses on a set of key technology elements to support critical mission capabilities. Project Pathfinder will support and interact closely with on-going NASA mission studies.


PAGE
PHOTOGRAPH

EXPLORATION TECHNOLOGY

The Exploration thrust will provide the critical technologies needed for gathering scientific and engineering data for robotic and piloted missions to the Moon, Mars, and other planets in the Solar System.

The program elements of the thrust are (1) Planetary Rover, (2) Sample Acquisition, Analysis, and Preservation, (3) Surface Power, and (4) Optical Communications. These elements have been designed to provide critically needed capability, while reducing cost and risk, for the advanced space systems essential to future robotic and piloted exploration of the Solar System.



One concept for a Mars Rover, collecting surface samples.

PLANETARY ROVER

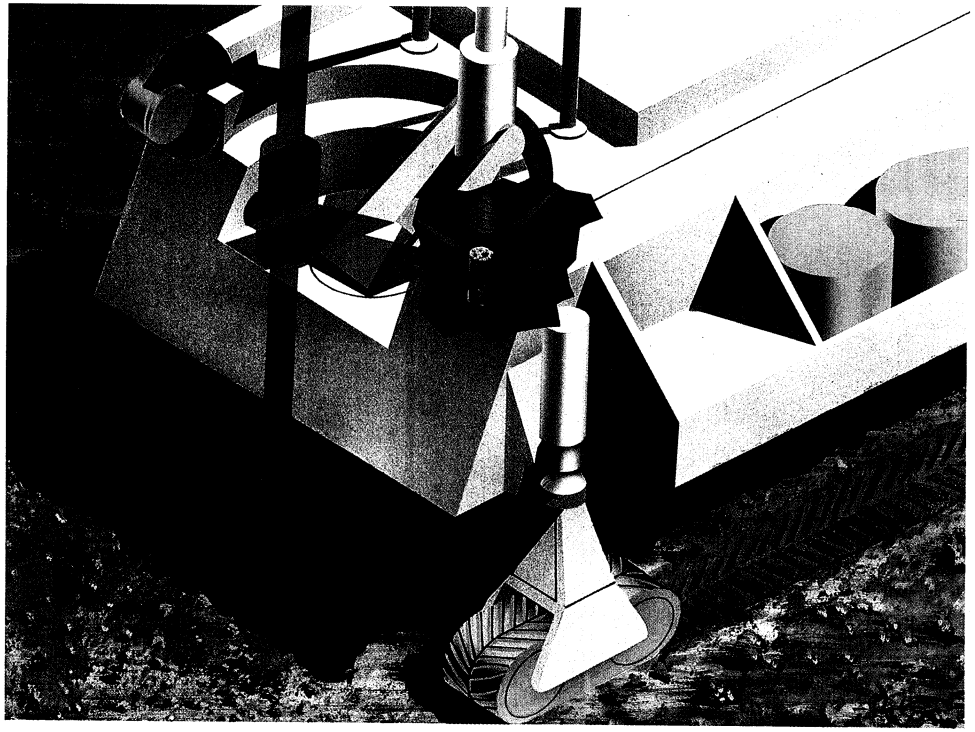
The Planetary Rover element will develop the technology base required for automated and human exploration of extensive areas of the Moon and Mars. These technologies will be applied in robotic exploration, in robotic precursors to piloted missions, and in systems for a Lunar outpost or piloted Mars missions.

The Planetary Rover element will focus on the development and integrated testing of technologies for (1) mobility and guidance to autonomously overcome or avoid hazards, (2) robotic sample acquisition, working in close cooperation with the sample analysis technology being developed in the Sample Acquisition, Analysis, and Preservation element, and (3) rover power, including compact, lightweight, high-capacity onboard power systems.

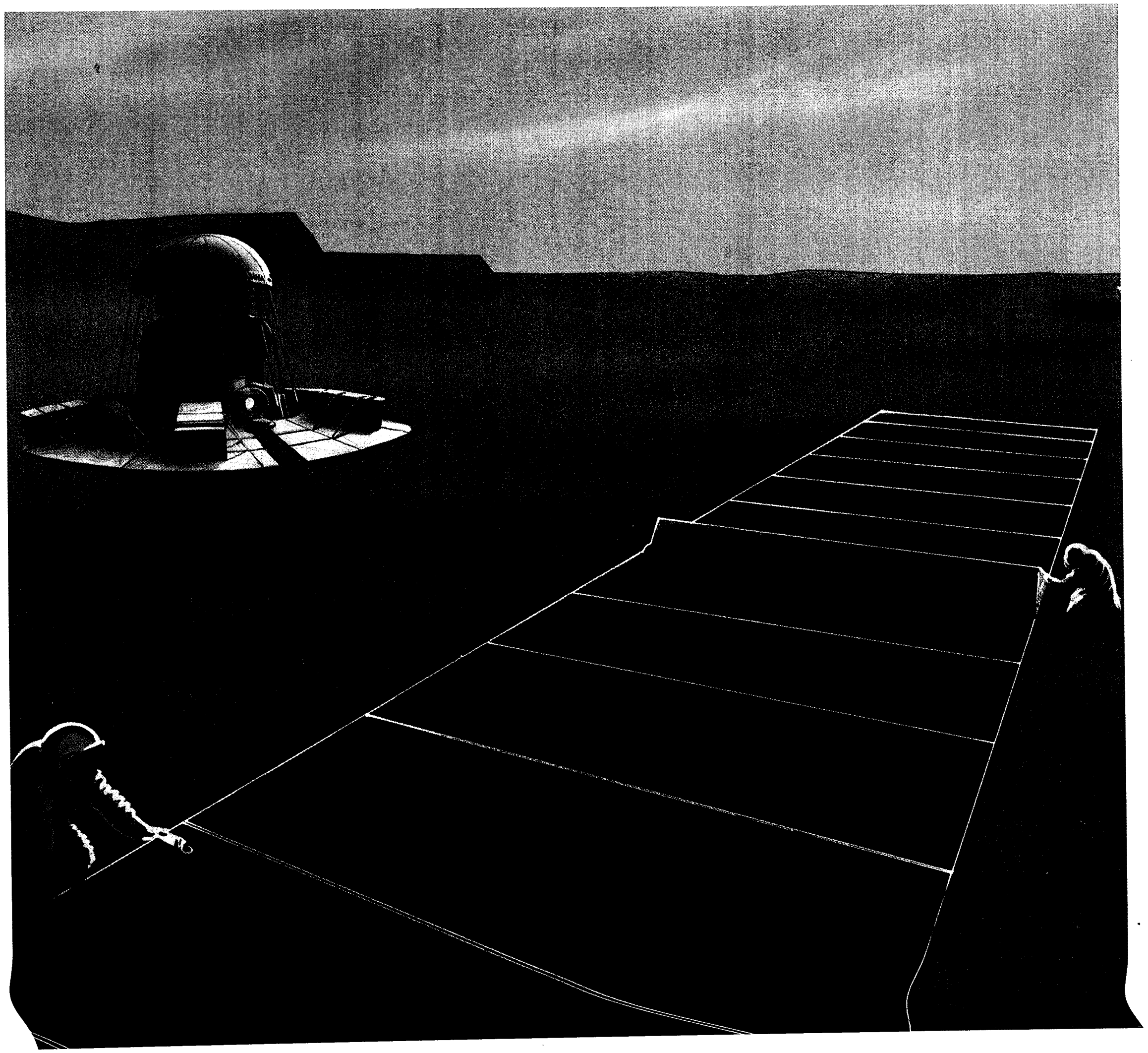
SAMPLE ACQUISITION, ANALYSIS, AND PRESERVATION

The Sample Acquisition, Analysis, and Preservation element will enable remote collection of chemical and mineralogical scientific data from a variety of planetary bodies. These technologies will support robotic exploration, robotic precursors to piloted missions, and supporting systems for a Lunar outpost or piloted Mars missions.

This program element will focus on the development of technologies for (1) sample acquisition, including tools developed in close cooperation with the robotic manipulation activities of the Planetary Rover element, (2) sample chemical and physical analyses, and (3) sample preservation, including thermal and pressure management.



Artist's conception of a core sample undergoing analysis after being obtained from below the planetary surface.



SURFACE POWER

The Surface Power element will address the technologies needed to meet mission requirements for high-performance, low-mass, high-reliability solar power for the early phases of a Lunar outpost as well as relatively short-duration piloted Mars missions. Technology advances will provide options applicable to Earth observation and to unpiloted planetary missions as well.

The program will focus on the development and testing of both power supply technologies (such as advanced photovoltaics and solar dynamics) and power storage (such as high-density fuel cells). Resistance to dust and chemical reactions in the Lunar and Martian environments is critical to performance.

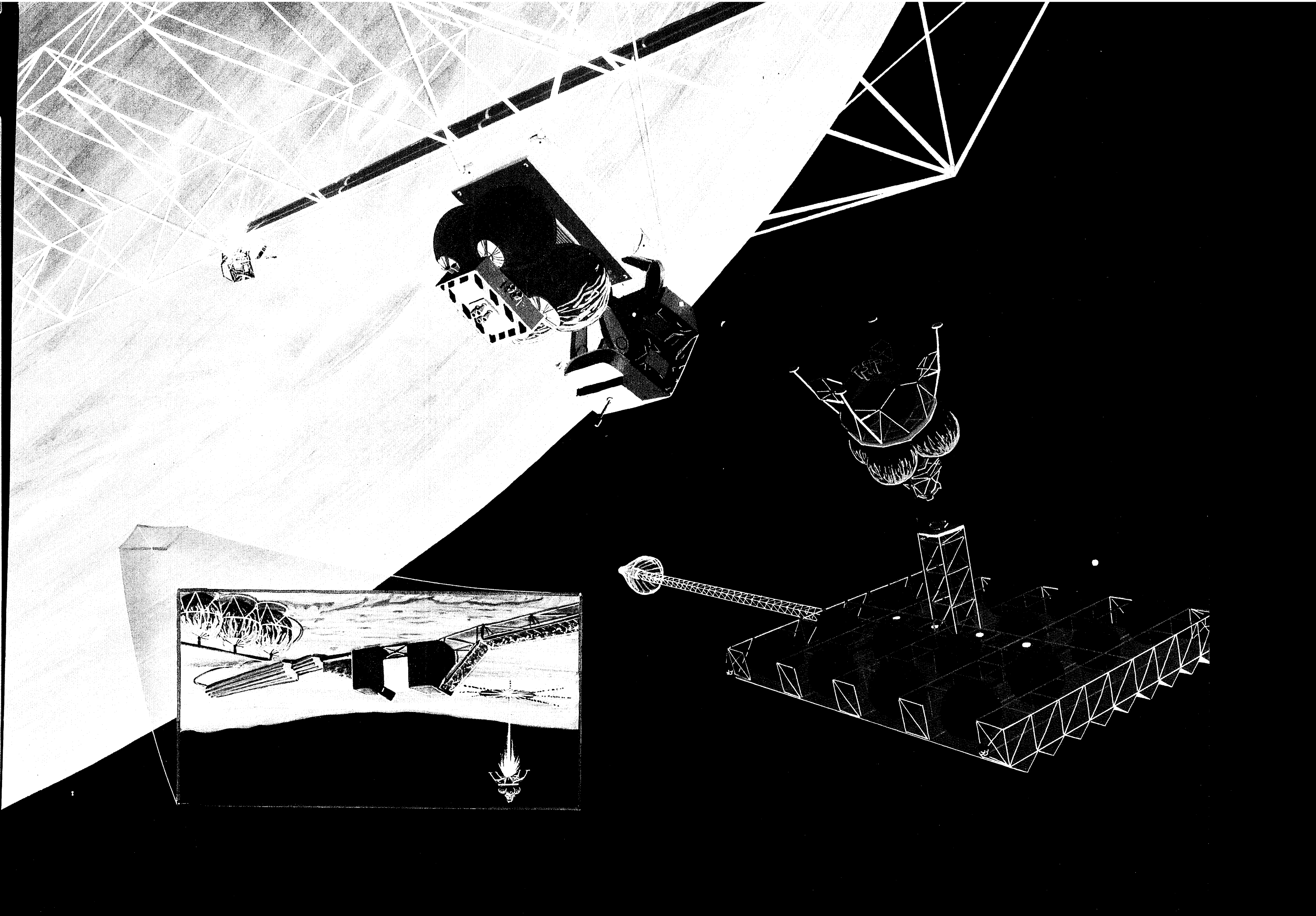
Astronauts laying out a photovoltaic power array on the surface of Mars.

OPTICAL COMMUNICATIONS

The Optical Communications element will provide the technology base required for the transmission of high-resolution data from deep space and planetary bodies for both robotic and piloted exploration missions.

The program will include the development of an optical communications acquisition and tracking detector. Critical hardware components will be developed, and methodologies such as control algorithms will be demonstrated. A flight test of this communications technology will demonstrate its feasibility.

A Saturn orbiter and an Earth-orbiting receiving station using optical technology.



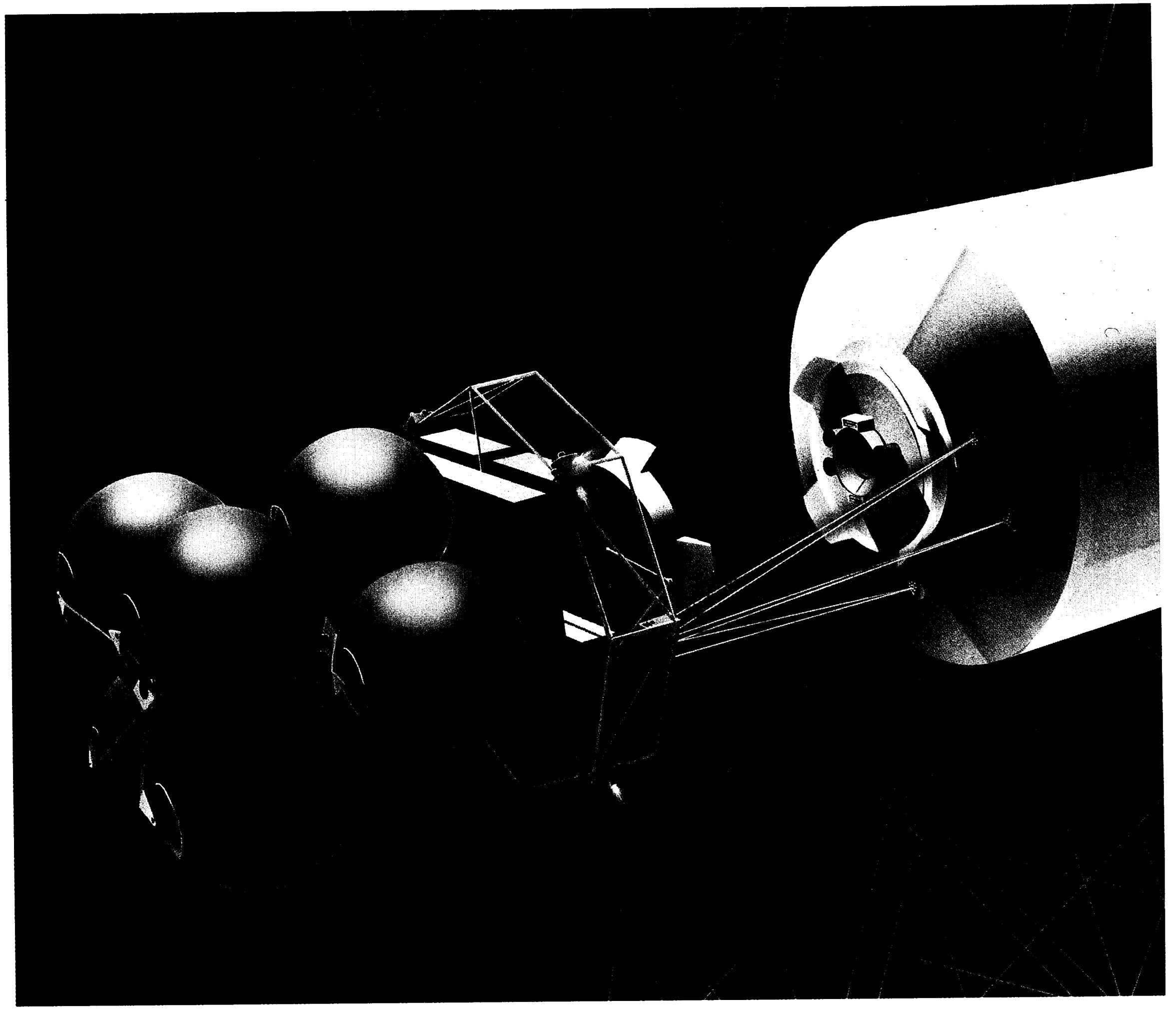
The Operations thrust will provide the technologies needed for Earth-orbit staging and operations, as well as operations at the Moon, Mars, and other planets in the Solar System.

The program elements of the thrust are (1) Autonomous Rendezvous and Docking, (2) Resource Processing Pilot Plant, (3) In-Space Assembly and Construction, (4) Cryogenic Fluid Depot, and (5) Space Nuclear Power (SP-100). These elements have been designed to augment capabilities substantially, while reducing cost, for the space infrastructure and operations inherent in missions in Earth orbit or for the robotic and piloted exploration of the Solar System.

AUTONOMOUS RENDEZVOUS AND DOCKING

The Autonomous Rendezvous and Docking element will develop technologies to enable reliable rendezvous and docking of nonpiloted space systems, as well as increasing the reliability and reducing the workload for piloted vehicles. This element will support efficient overall transportation in Earth orbit, for a Lunar outpost, or for robotic and piloted planetary missions.

The Autonomous Rendezvous and Docking element will address the development and testing of a variety of sensor technologies, including laser ranging and robotic vision. Techniques to combine onboard data from multiple sensors in real time will be developed. The application of fault-tolerant guidance, navigation, and control techniques will be demonstrated.



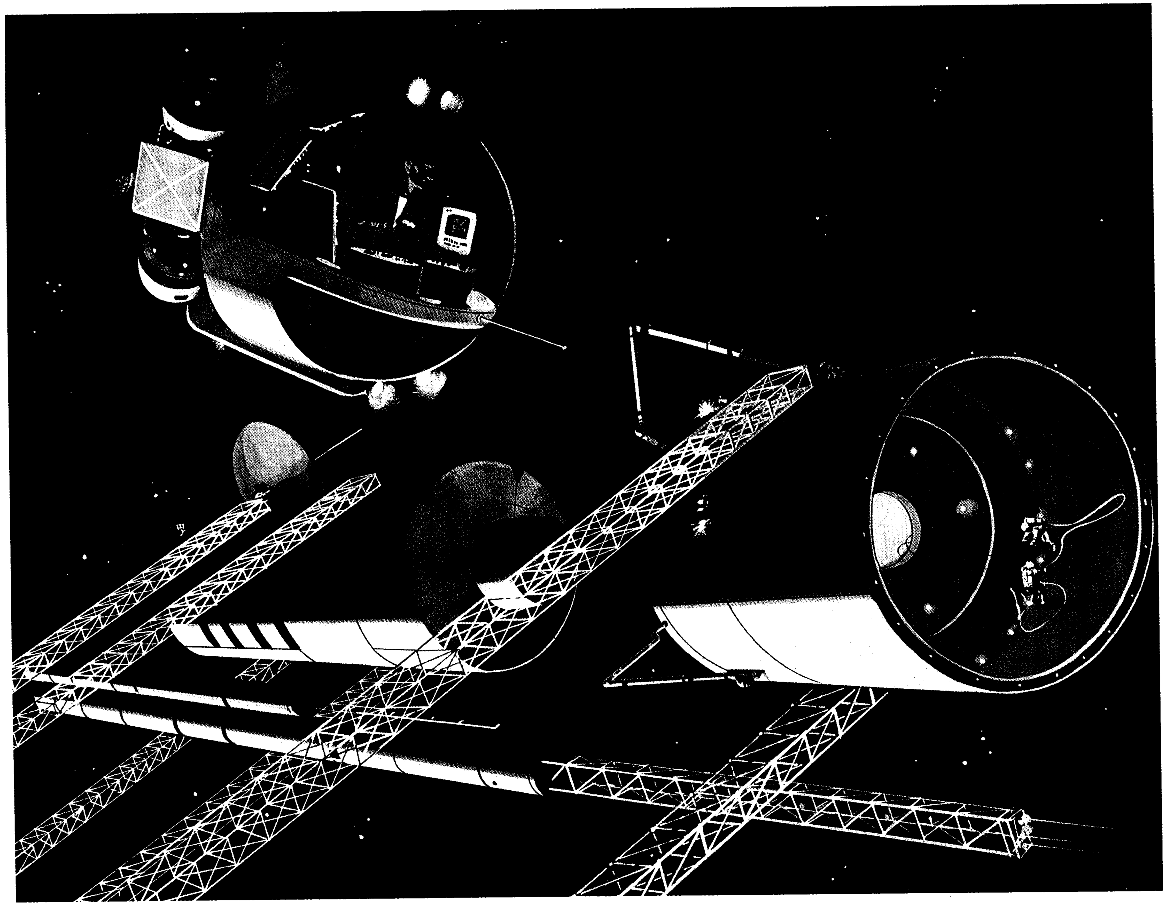
Using laser ranging to determine position, a fuel-carrying vehicle docks autonomously with a space station.

Operations of a fully active Lunar oxygen mining operation.

RESOURCE PROCESSING PILOT PLANT

The Resource Processing Pilot Plant element will develop the technologies needed (1) for collection, analysis, and both mechanical and electro/chemical separation of Lunar surface resources, (2) for production of materials needed for life support and propulsion (such as oxygen), and (3) for fabrication and construction of structural elements. These technologies will dramatically reduce dependence on Earth-to-orbit launch systems and high-cost Earth resources.

The Resource Processing Pilot Plant element will address a diverse assortment of technology development efforts. These include extraction and process-method identification and evaluation (attempting to achieve efficiency and low-power use, long life, low complexity, etc.) and telerobotic materials collection and handling.



Various newly developed technologies will be used to assemble large systems in low Earth orbit.

IN-SPACE ASSEMBLY AND CONSTRUCTION

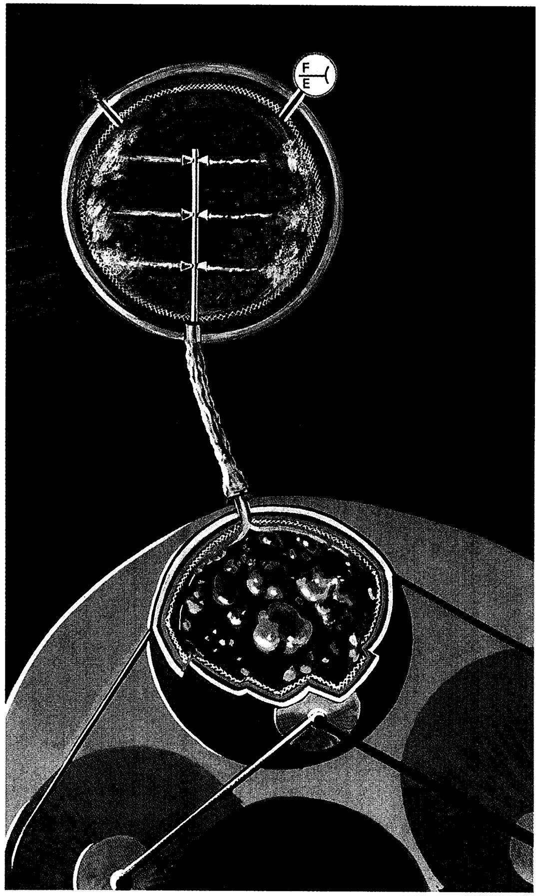
The In-Space Assembly and Construction element will develop focused technology required for robotic assembly and construction of large structures in space. It will support the development of a broad-based space infrastructure for the staging of large-scale missions; these include geostationary Earth-observing platforms, a Lunar outpost, and piloted Mars missions.

The program will address development and testing of (1) methods for manipulating and joining structural elements in space, using large, lightweight, and therefore highly flexible manipulators, and (2) mechanical and permanent joining methods such as welding.

CRYOGENIC FLUID DEPOT

Cryogenic Fluid Depot technologies will enable the design and development of efficient components and systems to service a broad array of space vehicles in microgravity. Cryogenic fluid transfers will be demonstrated that would enable a robust space station activity in support of missions to geostationary Earth orbits, the Moon, and the planets.

The Cryogenic Fluid Depot element will focus on the development and testing of large-scale cryogen containment, transfer, and refrigeration components and systems.

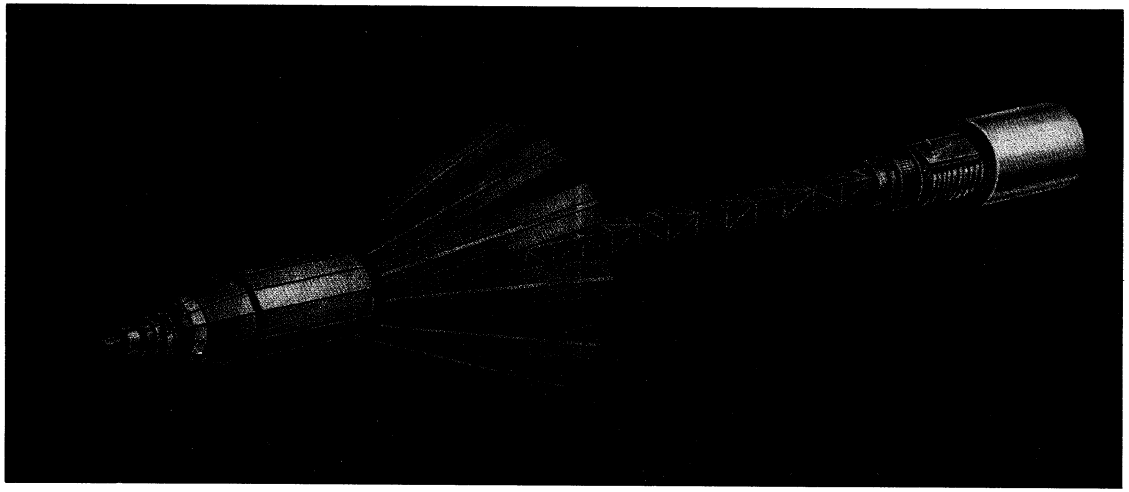


Handling cryogenic fluids in microgravity presents a variety of challenges.

SPACE NUCLEAR POWER (SP-100)

The Space Nuclear Power element will, in a joint NASA/DoD/DoE program, provide the technology base required for space nuclear power systems in the 10-kWe to 1-MWe range. This program will assure sufficient power, at substantially reduced mass, for selected Earth-orbiting spacecraft, a Lunar outpost, or piloted Mars missions.

The program will develop critical reactor power system components and subsystems; these will include (1) a refractory metal reactor capable of long life, (2) fuel pins, (3) a high-temperature control system, (4) a liquid-metal thermoelectric magnetic pump, and (5) high-efficiency, lightweight, thermal-to-electric conversion and heat pipe heat-rejection systems.



(Above) A deployed SP-100 space nuclear power system.

HUMANS-IN-SPACE TECHNOLOGY

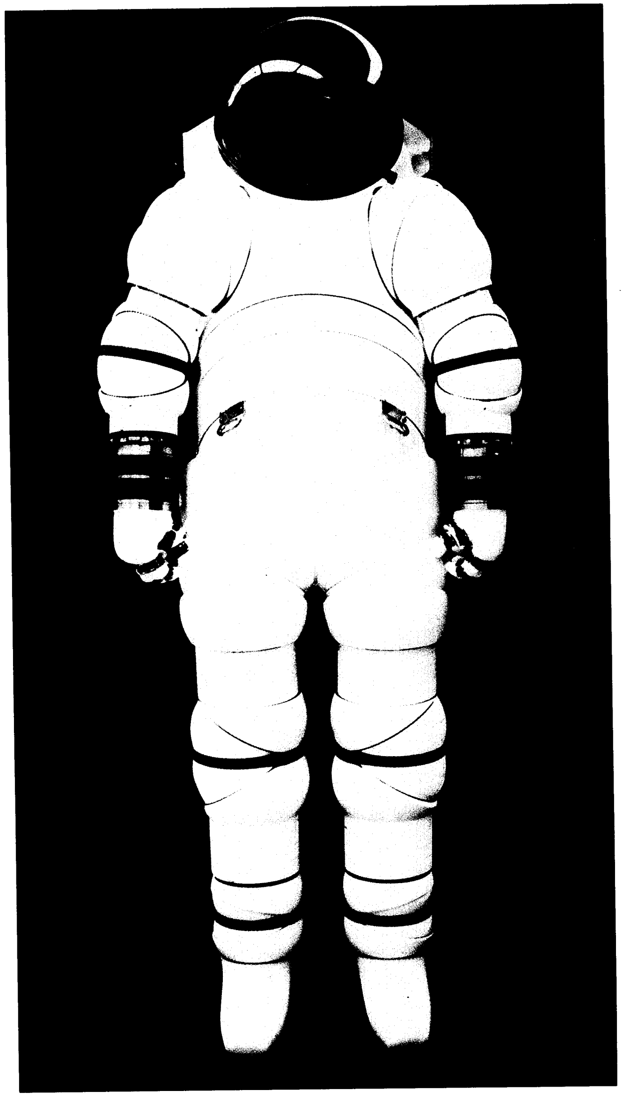
The Humans-in-Space thrust will provide the technology and understanding needed to ensure safe and productive human missions to the Moon, Mars, and other planets in the Solar System.

The program elements of the thrust are (1) Extra-Vehicular Activity/Suit, (2) Human Performance, and (3) Closed-Loop Life Support. These elements have been designed to provide the essential engineering systems to enable effective performance and good health during long-duration space missions.

EXTRA-VEHICULAR ACTIVITY/SUIT

The Extra-Vehicular Activity/ Suit element will provide the technology base required for long-duration, high-performance human activity. Mobility and dexterity in a system capable of long life and simple maintenance are key technology requirements.

The program will focus on development in two areas of technology: suit components and systems, and portable life-support concepts and components. Advanced materials and environmental counter-measures for surface suits will be developed, along with miniaturized components and improved thermal management systems.



An experimental "hard suit," which could support long-duration, low-fatigue astronaut operations.

HUMAN PERFORMANCE

The Human Performance element will ensure safe and productive human performance throughout and after long-duration space missions. Research into human capabilities and limitations for physical and cognitive work will be conducted; in addition, needed technologies will be identified, such as those for artificial gravity systems.

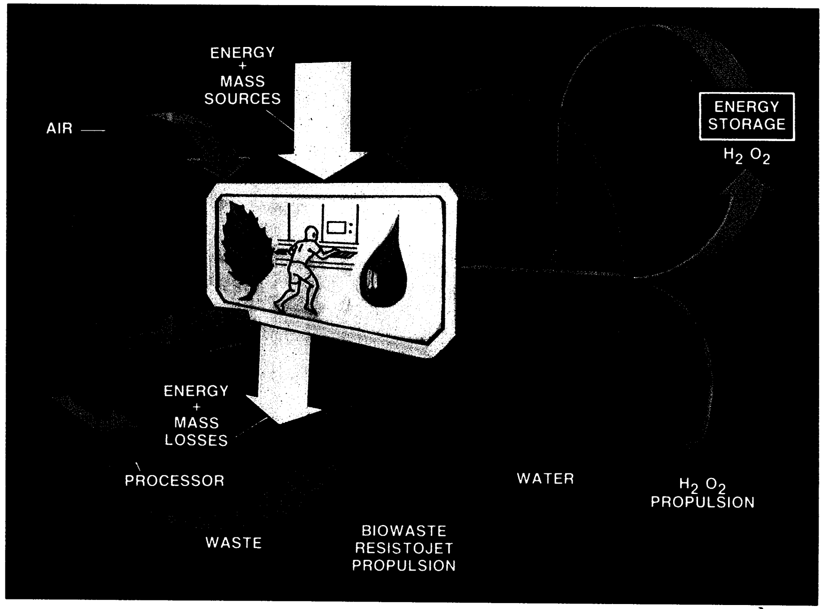
The program will focus on the research and development of technologies to help accommodate human physiological requirements and adaptive changes during long-term confinement, exposure to unnatural gravity, and unaccustomed risk and stress.

CLOSED-LOOP LIFE SUPPORT

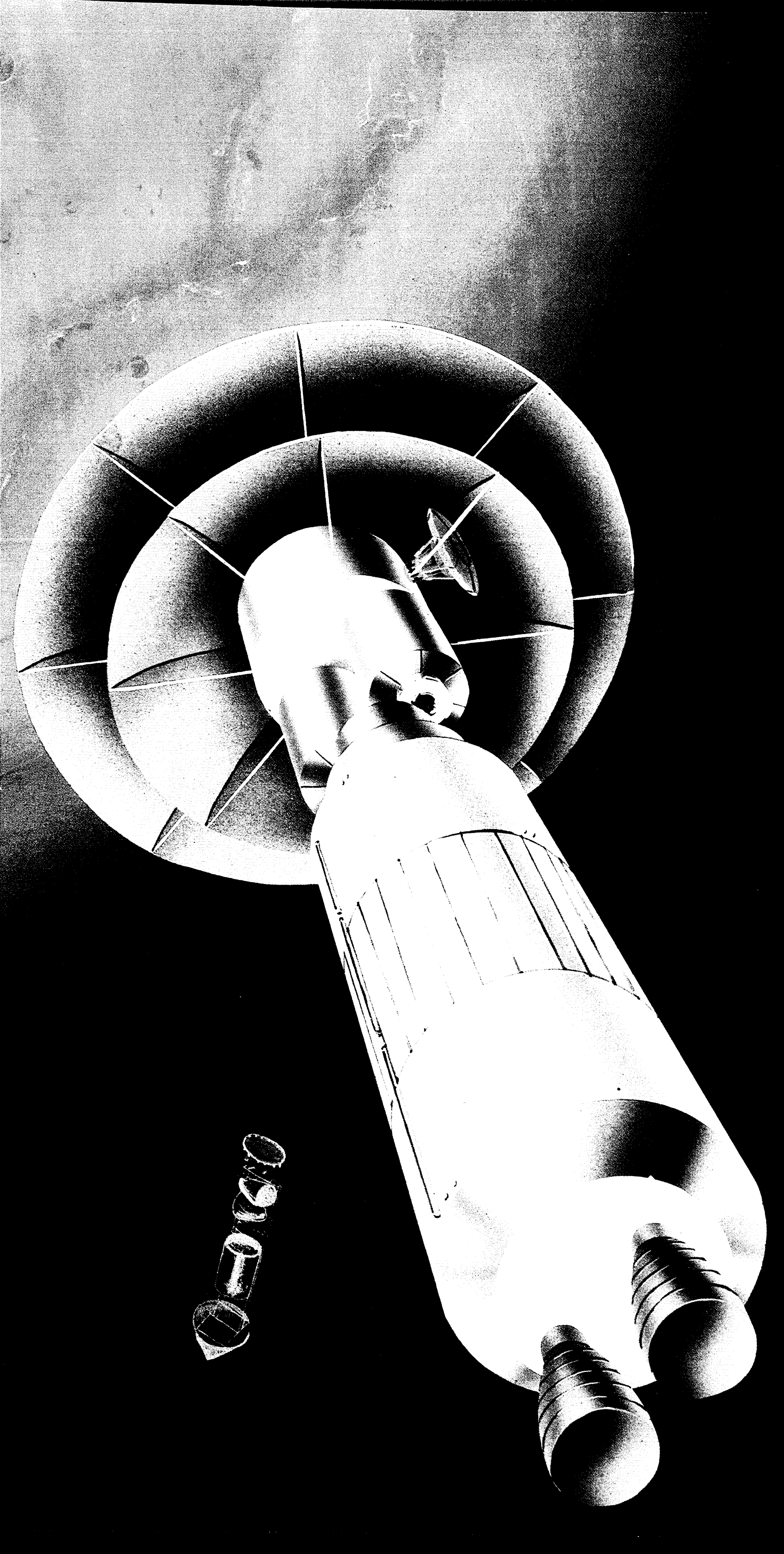
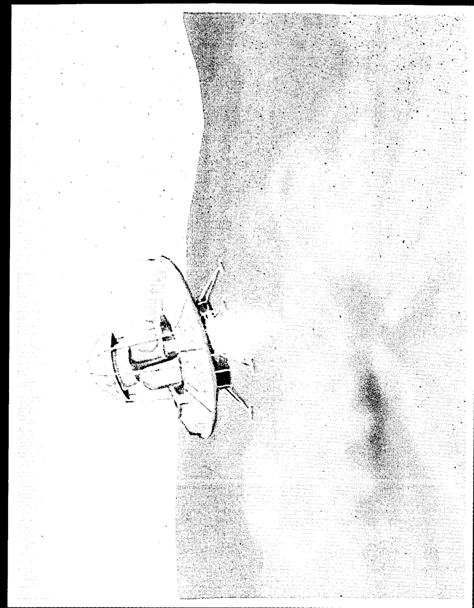
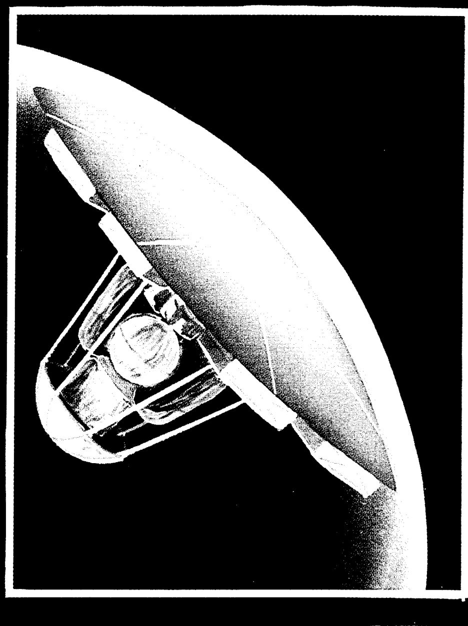
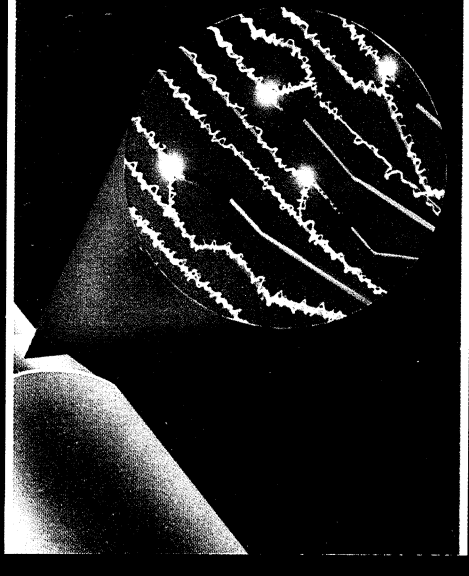
The Closed-Loop Life Support element will provide technologies that will substantially reduce the mass of consumables and, hence, the cost of resupply for long-duration human space operations.

The program will develop and test technologies for closed-loop life support systems, both chemical/physical process-based and plant-life-based. The program will define and test an optimal mix of the two approaches.

An illustration of some of the issues involved in human performance in space.

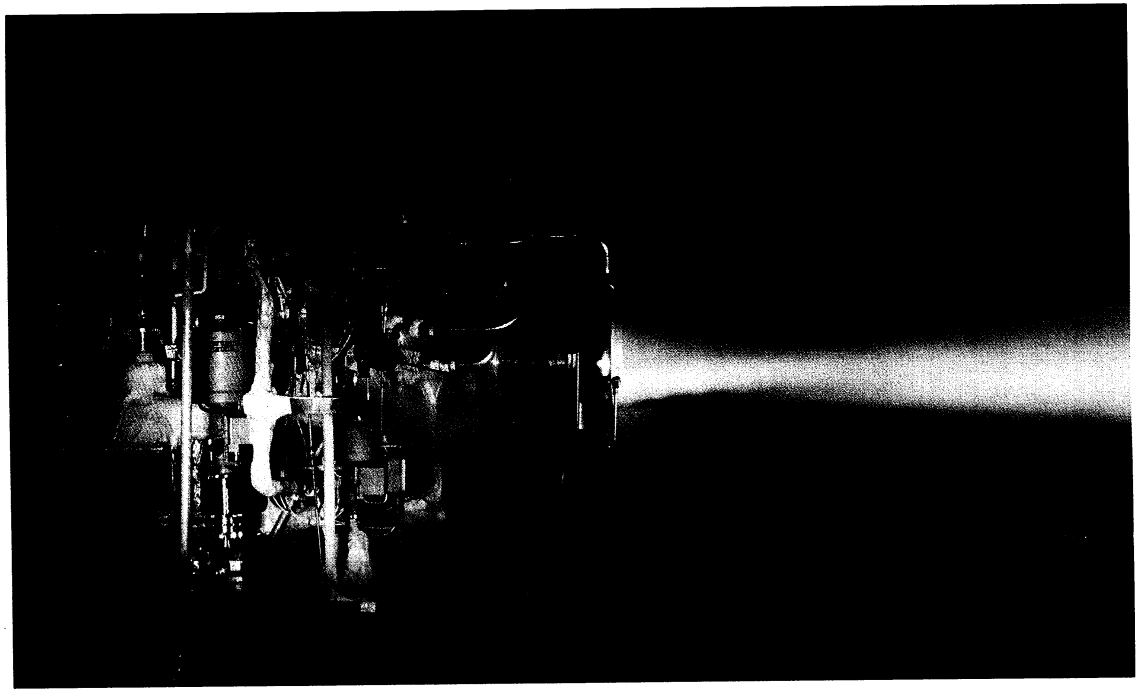


An illustration of some of the issues involved in closed-loop life support.

The Transfer Vehicle thrust will provide the critical technologies needed for transportation to, and return from, the Moon, Mars, and other planets in the Solar System, as well as for reliable and cost-effective Earth-orbit operations.

The program elements are (1) Chemical Transfer Propulsion, (2) Cargo Vehicle Propulsion, (3) High-Energy Aerobraking, (4) Autonomous Lander, and (5) Fault-Tolerant Systems. These elements have been designed to provide critically needed performance, while reducing both cost and risk, for the advanced space transportation systems that will be essential for a number of envisioned missions, including Earth-orbiting science and the robotic and piloted exploration of the Solar System.



An experimental cryogen-fueled rocket engine being test fired.

CHEMICAL TRANSFER PROPULSION

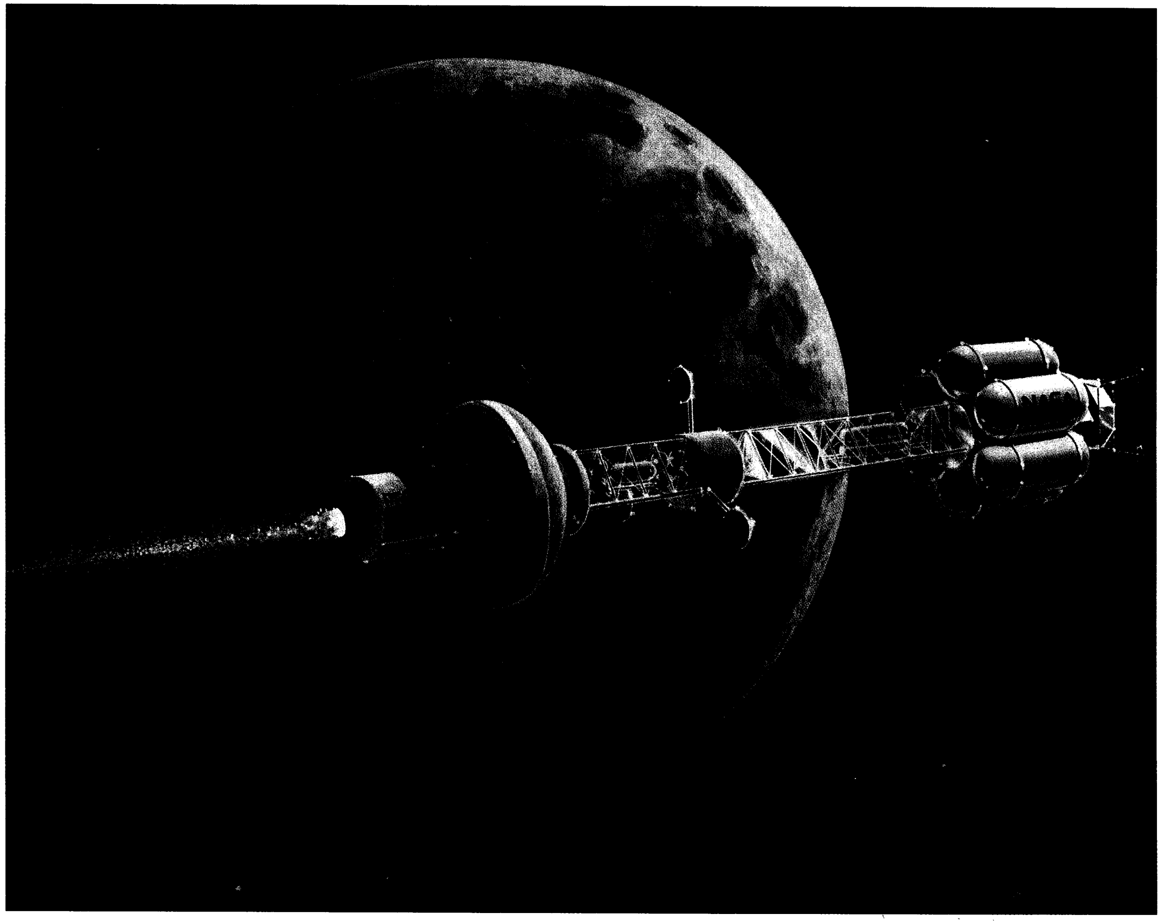
The Chemical Transfer Propulsion element will ensure the successful development of the propulsion technology for high-performance, space-based transfer vehicles, as well as for Lunar and Mars landers.

The focus of the program will be on the development of a validated design and analysis database for high-performance, fault-tolerant, liquid oxygen/hydrogen engines with in-space maintainability and automated operations. Key technical issues include high-heat combusters, high-pressure turbo-machinery, and system health diagnostics and controls.

CARGO VEHICLE PROPULSION

The Cargo Vehicle Propulsion element will develop very high performance electric propulsion technologies for use in supporting a piloted Mars mission and outer planet robotic exploration missions.

The program will focus on developing magnetoplasmadynamic (MPD) thrusters and establishing feasibility at high power levels. Key technical issues include MPD cathode lifetime and ability to create self-induced magnetic fields at megawatt power levels, and long-term performance testing.

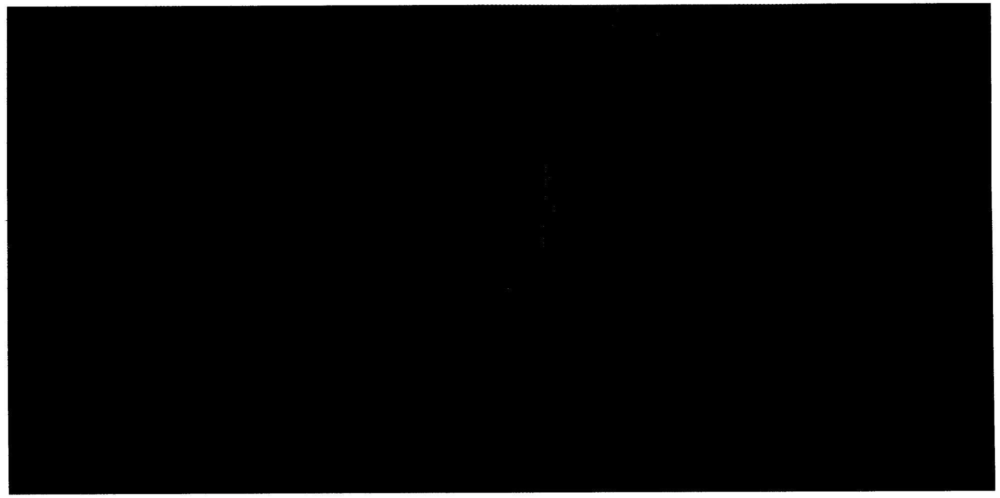


An electric propulsion cargo vehicle approaching Mars.

HIGH-ENERGY AEROBRAKING

The High-Energy Aerobraking element will provide the technology base required to perform high-enthalpy/high-velocity reentry, with significant reduction of mass in orbit. The reduction in onboard fuel for propulsive braking will enable efficient transportation for a Lunar outpost as well as both robotic and piloted missions to Mars.

The program will focus on the development of optimal performance aerobrake configurations and component technologies. Advanced materials for thermal protection systems and fault-tolerant and adaptive guidance, navigation, and control systems will be developed.



(Top) An experimental aerobrake configuration being wind-tunnel tested at Mach 20.

A vehicle landing autonomously in hazardous Martian terrain.

AUTONOMOUS LANDER

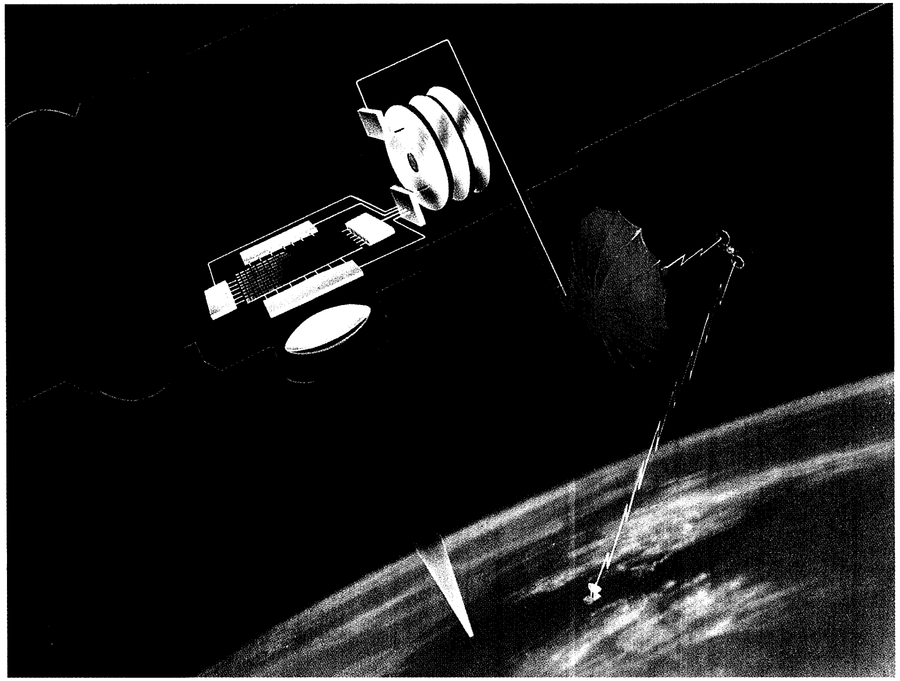
The Autonomous Lander element will provide the technology required to ensure a safe landing at geologically interesting sites, which are often hazardous, for a variety of potential science missions. These technologies will also support autonomous resupply operations for a Lunar outpost and reduce risks for piloted Lunar and Mars landing operations.

The program will focus on the development of terminal descent strategies and trajectory algorithms, as well as on guidance, navigation, and control designs, software, and sensors.

FAULT-TOLERANT SYSTEMS

The Fault-Tolerant Systems element will develop photonics-based technologies and systems architectures that will permit a dramatic improvement in overall system fault tolerance, while concurrently improving performance. Significantly improved reliability and performance will enhance Earth-orbiting spacecraft, robotic exploration missions, and long-duration human planetary missions.

The program will focus on the development and testbed evaluation of photonics-based technologies and systems, including prototype memories, input/output components, and communications components, as well as long-life, high-reliability photonic sensors.



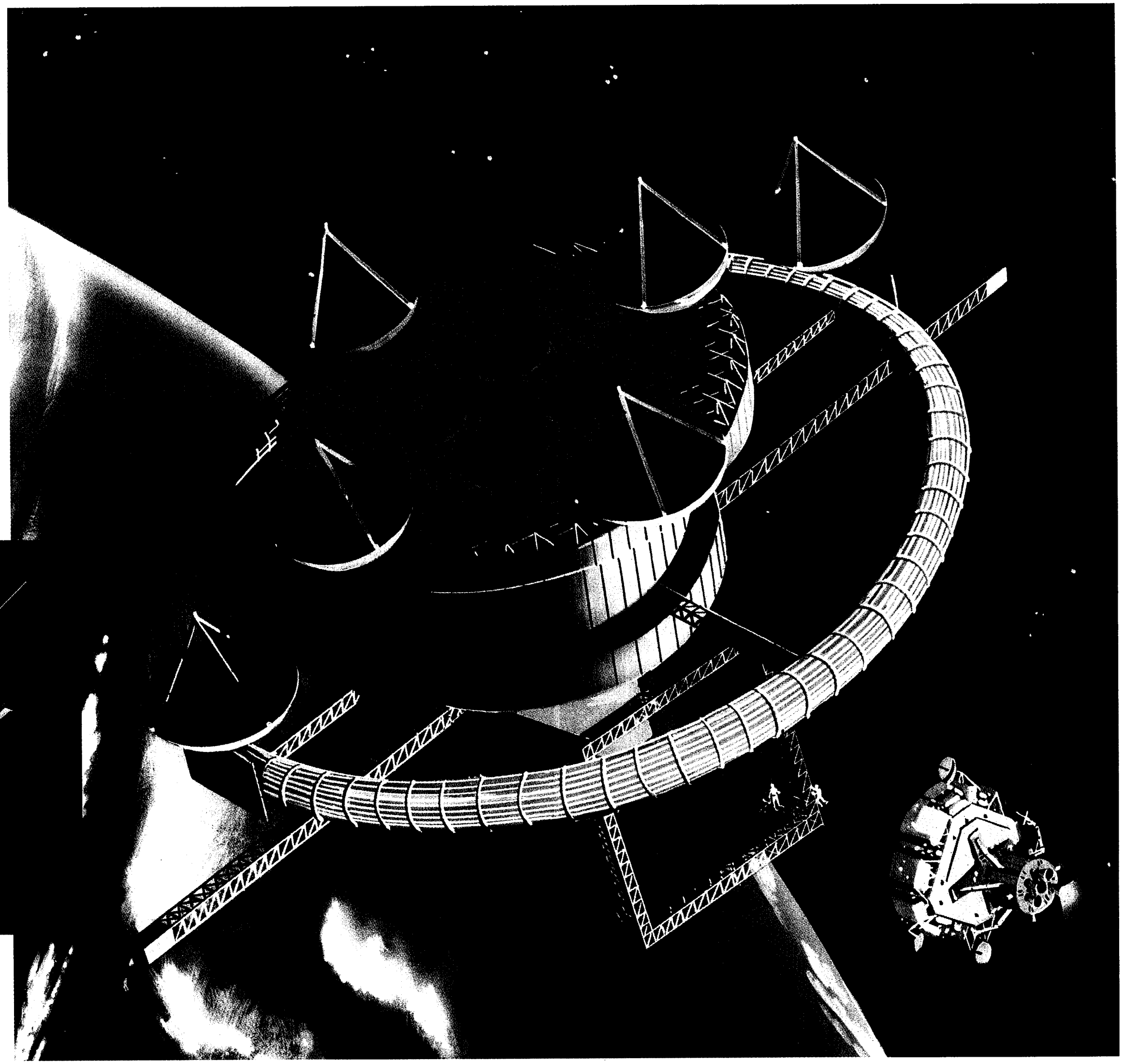
An illustration of potential photonic components in an Earth-orbiting application.

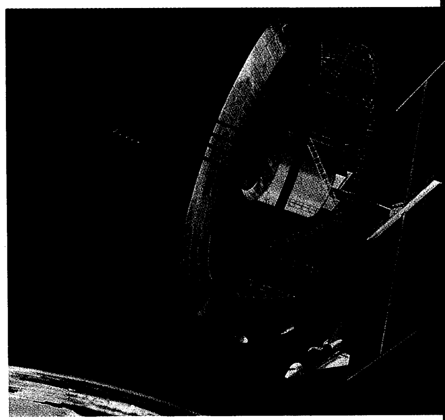
MISSION APPLICATIONS

The technologies developed under Project Pathfinder will support a broad array of potential new NASA missions. These include robotic exploration of the Solar System; spacecraft in Earth orbit, such as those to enhance our understanding of the Earth; Lunar outposts; and piloted planetary exploration missions.

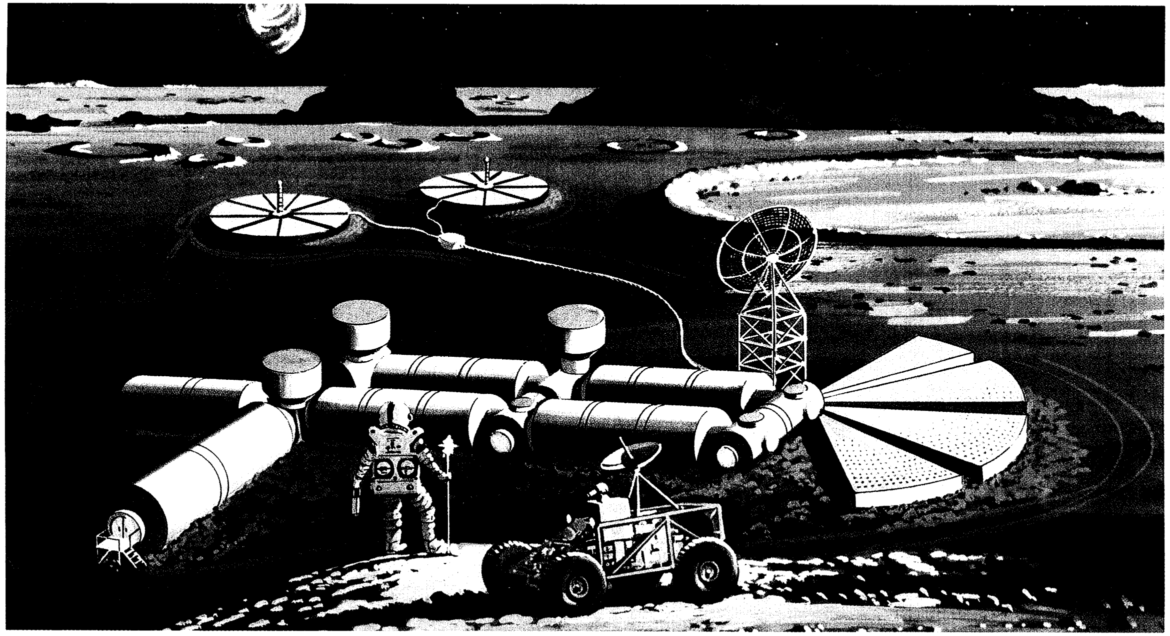
EARTH ORBIT

The technologies developed under Project Pathfinder will enable advanced Earth-orbit operations. Advanced space stations, and associated infrastructure, would utilize In-Space Assembly and Construction, Autonomous Rendezvous and Docking, Cryogenic Fluid Depot technologies, Extra-Vehicular Activity/Suit technology, and many technologies of the Transfer Vehicle thrust, to support mission staging and operations.





An advanced space station in low Earth orbit. (Inset) A large science observatory being staged in low Earth orbit.



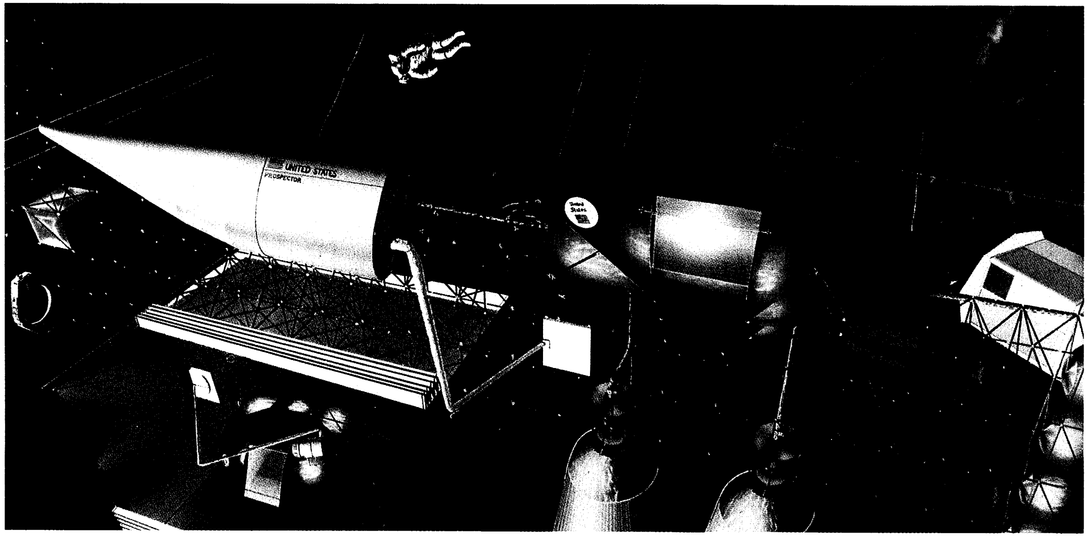
LUNAR OPERATIONS

A Lunar outpost would utilize Chemical Transfer Propulsion, Surface Power, Space Nuclear Power, and Resource Processing Pilot Plant technologies. An outpost would depend upon technologies from the Humans-in-Space thrust of Project Pathfinder.

An outpost on the Lunar surface, with space nuclear power units in the background.

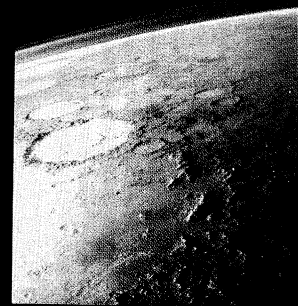
PLANETARY EXPLORATION

Robotic and piloted planetary exploration missions, for example to Mars, would require—in varying degrees—virtually all of the technologies developed under Project Pathfinder; key examples include Exploration technologies, Fault-Tolerant Systems, Autonomous Lander technology, and High-Energy Aerobraking.



An advanced planetary exploration mission is readied for launch from a space station in low Earth orbit.

By developing essential technologies, Project Pathfinder will provide the United States with the foundation for long-term leadership in space. It will enable a broad array of future civil space missions, including an intensive study of the Earth, a return to the Moon, and the robotic and piloted exploration of the Solar System. While furnishing options for exploration that currently do not exist and making future successes in space possible, Project Pathfinder will also push American technology forward through a strong partnership between NASA and U.S. industry and universities.



For additional
information on Project
Pathfinder, please
contact the NASA
Office of Aeronautics
and Space Technology,
Space Directorate,
Washington, D.C. 20546
Phone Number:
(202) 453-2733

National Aeronautics and
Space Administration
OAST
Office of Aeronautics and
Space Technology

ORIGINAL CONTAINS
COLOR ILLUSTRATIONS

400-330 12/87